Capabilities for Mars Exploration: Human Health & Support Systems

Dennis J. Grounds
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Human Health & Support Systems Capability Roadmap Team Members

ESMD Coordinators
- *Eugene Trinh, HSRT*
- *Betsy Park, HSRT*

Co-Chairs:
- *Dennis Grounds, JSC*
- *Al Boehm, Ret. Hamilton Sundstrand*

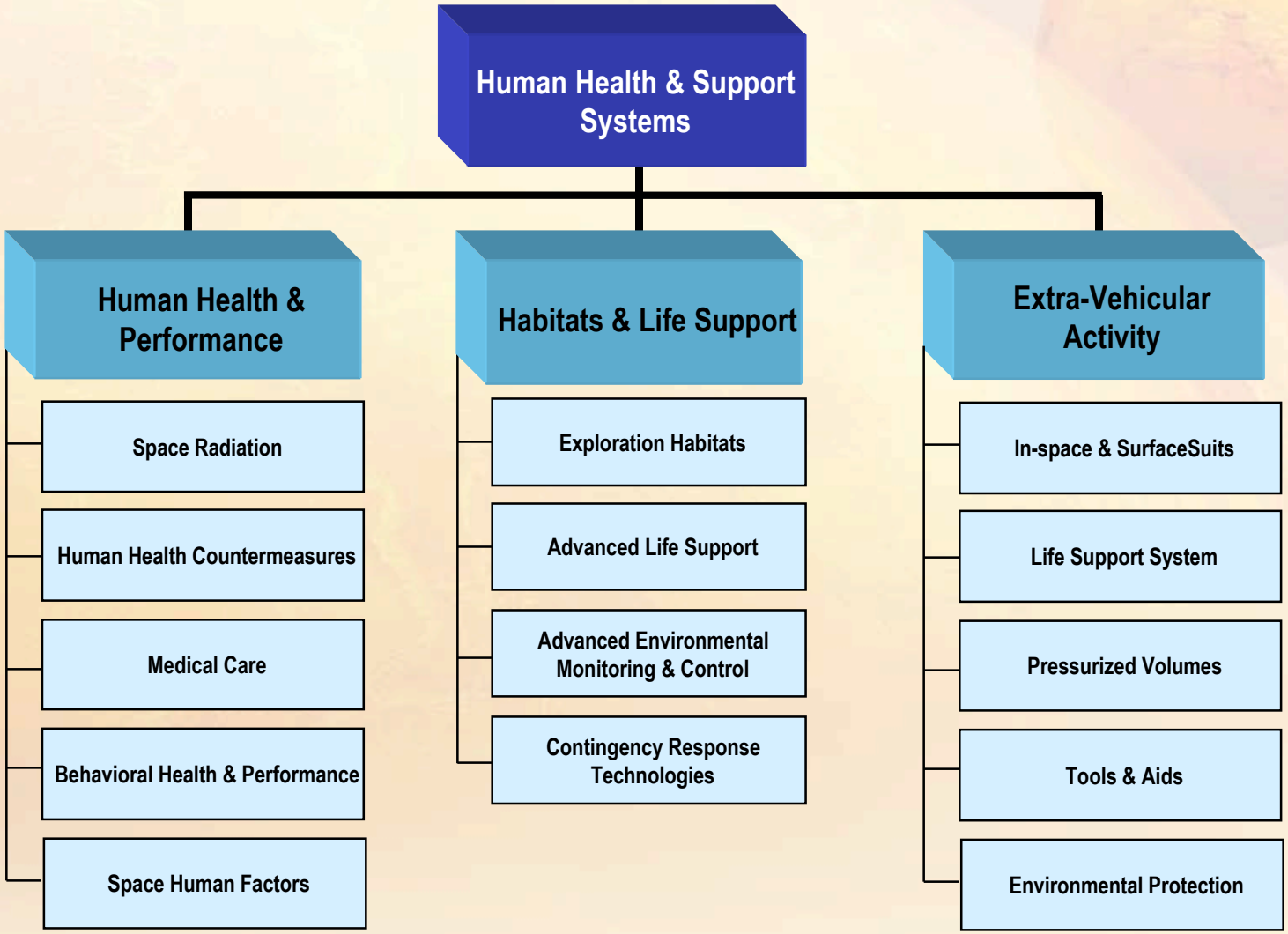
Academia
- *Dave Akins, Univ. of Maryland*
- *Jeanne Becker, NSBRI*
- *Robert Schlegel, Univ. of Oklahoma*

NASA
- *John Allen, HQ*
- *Robyn Carrasquillo, MSFC*
- *John Charles, JSC*
- *Gary Jahns, ARC*
- *Glenn Lutz, JSC*

Industry
- *Bernard Harris*
- *Robert Poisson, Hamilton Sundstrand*

APIO Coordinator
- *Jan Akins, JPL*

Capability Breakdown Structure



Human Health Critical Capabilities for Mars

1. Optimal radiation shielding solution for spacecraft.
2. Adequate warning systems and effective operational protection for Solar Particle Events.
3. Validated selection criteria for crewmembers that reduces personal risk and mission risk.
4. Validated countermeasure system that limits the deleterious effects of spaceflight to ensure crew health and performance, and provides the means by which observed deficits can be remedied.
5. Medical diagnostic capability to monitor all aspects of health, including predicted adaptation, and the means by which observed deficits can be remedied.
6. Optimized medical system to diagnose and treat the widest range of potential heath problems during all mission phases.
7. The best possible prediction of risk (including lifetime) to the crew from radiation exposure.
8. A system to support normal psychological adaptation to long duration spaceflight, and the means by which observed deficits can be remedied.
9. Accurate predictors of crew task performance during all mission phases.
10. Human Factors Engineering that prevents human error and maximizes successful performance.

Habitats & Life Support Critical Capabilities for Mars

1. Transport vehicle and surface habitat systems that meet the Human Systems Integration Standards for habitability
2. Water processing that effectively closes the system
3. Smaller, more reliable, air and water monitors
4. In situ environmental analysis capabilities
5. Improved fire prevention detection and suppression capabilities
6. Acceptable three-year food supply
7. More efficient thermal control capability
8. More effective air processing
9. Planetary protection-oriented waste management techniques
10. Integrated semi-autonomous control system

Habitat Critical Capabilities for Mars

- Habitat Functional capabilities include:
  - –Habitat Structure
    - Space transport vehicle habitation module
    - Surface modules
      - In-Situ Resource options
  - –Internal Systems
    - Life support systems (air, thermal, pressure, water, lighting)
    - Crew habitation systems
    - Housekeeping, Maintenance & Repair
    - Communications and data
  - –Environmental Systems
    - Dust control/Seals
    - Radiation Protection
    - Trash / Venting
  - –External Systems
    - Airlock
    - Micrometeoroid protection
    - “garage”

EVA Critical Capabilities for Mars

1. *Highly-integrated human-centric EVA suits for in-space operations and planetary surface operations*
2. *Task efficient EVA tools and equipment*
3. *Safe and effective EVA translation and mobility aids*
4. *Standard, modular human-centric rover vehicles interfaces*
5. *Human-interactive robotic assistants*
6. *Standard EVA sub-system interfaces*
7. *Functionally efficient airlocks*
8. *Ground support systems that effectively produce, test, train and maintain EVA systems*

Mars Missions Decisions Related to Human Health & Support Systems

	Mission Factors	Human Health	Life Support	Habitats	EVA
Mission Design	Transit time	X	X		
	Planetary stay	X	X	X	X
	Precursor Robotic Missions	X	X	X	X
Objectives	Location - single outpost/base/ alternate outposts?	X	X	X	X
	Surface Mobility/Range	X	X	X	X
	ISRU	X	X	X	X
Key Program Decisions	Crew Size	X	X	X	
	Artificial Gravity	X	X	X	
	Aerocapture	X			
	Robotic Assistants				X
	Lunar Missions as a testbed	X	X	X	X
	ISS as a testbed	X	X		

X = Critical X = Moderate

Human Health Countermeasures Roadmap

Current SOA:
- ISS Exercise HW and Rx
- Fluid loading
- Re-entry Anti-g suits
- Prebreathe Protocol
- Recumbent seat
- Liquid Cooling Garments

Exploration Requirements and Medical Standards & Bioastronautics Roadmap

Individual Investigators: Understand scientific basis of problem: Formulate countermeasure concept

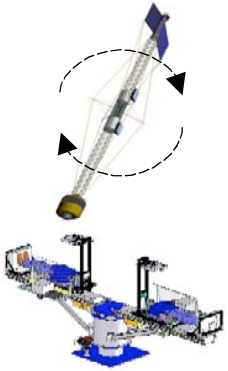
Focused research teams: Demonstration of CM efficacy Laboratory/ clinical testing

CM evaluation with human subjects in simulated spaceflight environment

CM validated with human subjects in Actual Spaceflight environment

Countermeasure operational

Test individual CM on ground and ISS	Test candidate CM suites on ISS	Validate integrated CM suite	Develop lunar and Mars CM systems
▸ Baseline program plan for Physiological Countermeasures ▸ Define, develop and test next generation exercise H/W ▸ Develop predictive models of adaptation ▸ Develop and optimize Spaceflight analogs for C/M development	▸ Deliver and validate next Gen Exercise H/W to ISS ▸ Test and validate integrated predictive models of adaptation ▸ Define Lunar system requirements for exercise and other physiological CM		▸ Deliver Validated Countermeasure suite (lunar) for development ▸ Develop and implement training tools for lunar crews ▸ Refine predictive models of adaptation ▸ Define Mars system requirements for exercise and other physiological CM



Continuous AG Trade Study (radius, spin rate, spin up/down time)

Develop evidence base for AG decision (continuous, intermittent, surface ops)

Spin Vehicle?

yes

no

Intermittent AG Trade Study (radius, spin rate, duty cycle, mass/volume/power)

ISS Milestones — Retire Shuttle — End of US participation

Manned Exploration Milestones

Spiral 1.X SRR SDR PDR CDR Launch — 1st Crewed CEV flight

Spiral 2 SRR SDR PDR CDR Launch — 1st Human Moon Mission

Long Duration Human Moon Mission

Spiral 3.x SRR SDR PDR CDR Launch

1st Human Mars Mission

Spiral 4- 5 SRR SDR PDR CDR Launch

CRR

FY	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Earliest Mars Countermeasure Decision Point

Capability Gaps: Space Radiation

Roadmap	Current Capabilities	Capability Gaps	Deliverables	Benefits
Spiral 1 Crew of 4-6 to Low Earth Orbit (2014)	• Shuttle & Station Monitoring and shielding • LEO Exposure Limits • LEO Risk Assessment		• ALARA requirements for shielding & monitoring • Risk Assessment and Crew Constraints	• Risk Reduction • Efficiency Increase
Spiral 2 Crew of 4-6 to Lunar Surface for Extended Duration (2015-2020)	• Same as Spiral 1	• Lunar Exposure Limits	• ALARA requirements for shielding and monitoring • Exposure Limit Recommendations • Risk Assessment and Crew Constraints	• Risk Reduction • Efficiency Increase
Spiral 3 Crew to Lunar Surface for Long Duration Stay (2020-TBD)	• Same as Spiral 1	• SPE Warning Requirements • Radiation Shielding materials & analysis • Radiation Countermeasures • Lunar Mission Exposure Limits • Acceptable Risk	• Same as Spiral 2 PLUS • Risk Assessment, Crew selection recommendations & constraint criteria • Optimized Radiation Shielding Solutions • Flight rules & operations constraints	• Risk Reduction • Efficiency Increase
Spiral 4 Crew to Mars Vicinity (2030+)	• Same as Spiral 1	• Same as Spiral 3	• Same as Spiral 3 PLUS • Requirement for direct comm to space weather satellites	• Risk Reduction • Efficiency Increase

Capability Gaps: Advanced Life Support (Water Recovery)

Roadmap	Current Capabilities	Capability Gaps	Deliverables	Benefits
Spiral 1 Crew of 4-6 to Low Earth Orbit (2014)	• Stored Water • Iodine Disinfection	• Improved Disinfection		

Spiral 2
Crew of 4-6 to Lunar Surface for Extended Duration (2015-2020)
	• Stored Water
	• Iodine Disinfection
		• Improved Disinfection	• Water reclamation options
			  • Vapor Phase Catalytic Ammonia Removal System
			  • Cascade Distillation System
			  • Direct Osmotic Concentrator
				• Risk Reduction
				• Efficiency Increase

Spiral 3
Crew to Lunar Surface for Long Duration Stay (2020-TBD)
	• Distillation (~87.5% Recovery)
	• Multifiltration & Ion Exchange
	• Catalytic Oxidation
	• Iodine Disinfection
		• Distillation with >90% recovery
		• Ambient temp oxidation
		• UV oxidation
		• Photocatalysis
		• Bioregenerative water processing
		• Brine recovery
			• Closed loop water system technologies
			  • Biological Water Processor
			  • Brine recovery
			  • Improved post-processing system
				• Risk Reduction
				• Efficiency Increase

Spiral 4
Crew to Mars Vicinity (2030+)
	• Distillation (~87.5% Recovery)
	• Multifiltration & Ion Exchange
	• Catalytic Oxidation
	• Iodine Disinfection
		• Distillation with >90% recovery
		• Ambient temp oxidation
		• UV oxidation
		• Photocatalysis
		• Bioregenerative water processing
		• Brine recovery
			• Closed loop water system technologies
			  • Biological Water Processor
			  • Brine recovery
			  • Improved post-processing system
				• Risk Reduction
				• Efficiency Increase

Capability Gaps: EVA

Roadmap	Current Capabilities	Capability Gaps	Deliverables	Benefits
Spiral 1 Crew of 4-6 to Low Earth Orbit (2014)	• Shuttle Launch and Entry Suit (LES) • Extravehicular Mobility Unit (EMU)	• In-space Suit which supports both launch and entry and contingency EVA	• Umbilical Life Support System (LSS) • Full pressure survival garment w/ contingency EVA mobility • Tools to support contingency EVA, Common across missions	• Crew survivability • Contingency repair • Risk Reduction • Efficiency Increase
Spiral 2 Crew of 4-6 to Lunar Surface for Extended Duration (2015-2020)	• Shuttle LES • Extravehicular Mobility Unit	• Surface Suit with surface mobility and Lunar environment protection	• Lunar environment LSS • Mobile walking suit • TBD, Common across missions	• Crew survivability • Human exploration of planetary surface
Spiral 3 Crew to Lunar Surface for Long Duration Stay (2020-TBD)	• Shuttle LES • Extravehicular Mobility Unit	• Surface Suit with surface mobility and Lunar environment protection	• Lunar environment LSS • Mobile walking suit, upgraded for long duration mission. • TBD, Common across missions	• Crew survivability • Human exploration of planetary surface
Spiral 4 Crew to Mars Vicinity (2030+)	• Shuttle LES • Extravehicular Mobility Unit	• In-space Suit which supports both launch and entry and contingency EVA	• Umbilical LSS • Full pressure survival garment w/ contingency EVA mobility • Tools to support contingency EVA, Common across missions	• Crew survivability • Contingency repair • Risk Reduction • Efficiency Increase

Next Steps

- *10 March - Deliver draft for National Academy of Engineering (NAE) Review Phase 1*
- *17 March – Dialogue with the NAE*
- *15 April – Receive strategic roadmap products*
- *16 April-12 June – Revise roadmap*
- *12 June – Deliver second roadmap product to NAE for Review Phase 2*
- *Mid July – Phase 2 review with the National Academy of Engineering*
- *Mid September – Deliver final roadmap product*

Summary

- *Human Health and Support Systems are critical to overall mission success*
- *The Mars Strategic Roadmap and other key program decisions contain drivers to the capability roadmap*
- *The capability roadmap can and will be iterated based on:*
  - *Mars Strategic Roadmap decisions*
  - *Lunar Strategic Roadmap decisions*
  - *Feedback from the National Academy of Engineering*
  - *Program technical and budgetary decisions from ESMD*
- *With appropriate investment, Human Health & Support Systems will not limit Mars Exploration strategic planning decisions*